Production and Nutrient Value of Elephant Grass in Agroforestry Systems in Indonesia

by Didik Wisnu Widjajanto

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Endang Dwi Purbajanti[1*], *Didik* Wisnu Widjajanto[1], *Praptiningsih* Gamawati Adinurani[2], *Zahid* Hussain[3,4], and *Ida* Ekawati[5]

[1]Faculty of Animal Husbandry and Agriculture Sciences, Diponegoro University, Jl. Prof. Soedarto No.50275, Tembalang, Semarang 50275, Central Java, Indonesia
[2] Faculty of Agriculture, Merdeka University of Madiun, Jl. Serayu No.79, Madiun 63133, East Java, Indonesia
[3]Department of Weed Science and Botany, The University of Agriculture, Peshawar, 25130, Khyber Pakhtunkhwa, Pakistan
[4]Postdoc Scientist, The Ohio State University, 281 W Lane Ave, Columbus, OH 43210, USA
[5]Department of Agribusiness, Faculty of Agriculture, Wiraraja University, Jl. Raya Pamekasan - Sumenep Km. 05, Patean, Sumenep 69451, East Java, Indonesia

Abstract. Research on elephant grass with 2 x 2 factorial repeated five times has been carried out at AGRO-1 and AGRO-2, Tuntang watershed**.** Observed variables were: plant height, forage production, dry matter content, crude protein, crude fiber. Soil samples were observed including soil bulk density, pH, and total N. Plant height in AGRO-1 was higher (85.1 cm) than in the AGRO-2 system (71.5 cm). Season affects plant growth as indicated by lower plant height in the dry season (66.8 cm) than in the rainy season (89.8 cm). The AGRO-1 system has a better forage yield than the AGRO-2 system. Forage dry matter varies between agroforestry systems and seasons. The lowest DM is in the rainy season at AGRO-1. Crude protein in AGRO-1 is lower than in AGRO-2. The highest protein content in AGRO-1 in the rainy season (11.3 %), the lowest in AGRO-2 in the dry season (6.0 %). The crude fiber of elephant grass in AGRO-2 is higher than in AGRO-1. The crude fiber content in the dry season is higher than in the rainy season. The conclusion of this study was that elephant grass in AGRO-1 had better growth, production, and quality than in AGRO-2.

Keywords: Crude protein, crude fiber, forage production, nitrogen, *Pennisetum purpureum* Schumach.

1 Introduction

In Indonesia, generally, livestock rearing includes agricultural activities. Forage fodder is supplied from agricultural land and agricultural waste owned by farmers. At the research location, livestock activities are included in the agroforestry farming system. Farmers grow elephant grass together with other crops on their land. Elephant grass (*Pennisetum purpureum* Schum.) is one of the superior grasses for preventing erosion and increasing soil fertility, especially in upstream areas [1] Feed accounts for a large portion of the total cost of dairy cattle production in Indonesia because more than 70 % of livestock rations consist of forage feed [2]. Apart from being a source of forage for ruminants, forage can also be used for the conservation of land resources.

Agriculture is widely accepted as one of the sectors most at risk of climate change due to increasing temperatures, low rainfall, and increasing frequency of climate change especially in the tropics [3–5]. Agroforestry is defined as 'an intensive land management system that optimizes the benefits of biological interactions between trees and shrubs that are intentionally combined with crops and livestock. Agroforestry systems are of great interest because they have the advantage of contributing large amounts of above-ground biomass and tree root systems that are able to penetrate the soil to deep sites [6, 7]. Agroforestry systems are perceived to offer increased opportunities for combining procurement services with other types of services (regulating, supporting, or even cultural). This system consists of mixed trees and crops or livestock and presents a complex spatial and temporal structure. The potential environmental benefits of having trees in an agroforestry system include habitat and shelter for biodiversity, carbon sequestration, microclimate regulation, and nitrogen fixation by leguminous species. In addition, many livelihoods in developing countries in the tropics depend on agroforestry as a subsystem, economic income, and other services, for example, timber sales and food security [8, 9]. Agroecosystems, as interfaces between human societies and natural ecosystems, are defined as systems and communities of plants and/or animals that interact with their physical and chemical, ecological, and socioeconomic environments that have been modified by people to produce food, fiber, or other agricultural products for human

* Corresponding author: endang.purbajanti@live.undip.ac.id

consumption as well as for processing [10]. Agroforestry research begins by studying the existing traditional practices of local communities, which forms the basis for conducting experimental research. As agroforestry research progresses, researchers are discovering the high potential of agroforestry to address many of today's environmental and social problems, such as climate change and food security [11].

Grasslands and agricultural land have been indicated to be more efficient than permanent cropping systems in terms of organic C uptake, nutrient availability, and increased agrosystem biodiversity [12]. Nitrogen (N) is a major nutrient, which, due to its limited availability to plants, appears as a limiting factor for plant growth and development in diverse agricultural ecosystems. N is absorbed from the soil solution and used for various metabolic purposes [13], including the production of nucleic acids, the formation of proteins and cofactors. It is part of chlorophyll and is one of the main components required for photosynthesis, as well as its role in signaling and storage molecules [14–16]

Increased crop production will increase the amount of plant biomass and its return to the soil as plant residues and roots. This has the potential to increase soil organic matter and affect soil structure and stability [17, 18]. Diversity soil microbiology, microbial biomass, and respiration are influenced by the intensity and diversity of crops. Changes in soil quality can affect crop yield potential and the number and distribution of roots in the soil profile [19]. The sustainability of cropping systems requires nutrient replacement and soil fertility. Plants have different yield potentials and the number of nutrients removed from the soil. Therefore, the number of nutrients applied must be based on the nutrient requirements of the plant. Intensification and diversification of cropping systems affect nutrient requirements, their cycles and distribution in the soil profile, affect nutrient requirements and dynamics in crop rotation [20]. Nutrient management requires nutrient requirements that are right for plant needs. If this relationship is not managed, it will result in loss of crop yields and quality as well as loss of nutrients in the environment resulting in loss of nutrient use efficiency and increasing the potential for degradation of air, water, and soil quality [21, 22]. Soil ecosystem functions to a certain extent have a strong relationship with soil biogeochemical processes, namely the relationship between biological, chemical, and geological processes. Soil is an important element of life support systems because it provides several ecosystem goods and services such as carbon storage, water regulation, soil fertility, and food production, which have an impact on human well-being [23, 24]. The success of the forage cultivation business is highly dependent on several factors, including the type of forage, climatic conditions, water, and soil fertility. Soil is an important element in the growth of fodder forage because the soil functions as a place to grow, where plants obtain nutrients and become a source of water for plants [25, 26]. Many kinds of research on elephant grass have been carried out, but the production and nutritional value of elephant grass in agroforestry systems are still interesting to study. The purpose of this study was to determine soil fertility, growth, production, and quality of forage in agroforestry systems in the upstream area of the Tuntang, Central Java, Indonesia watershed.

2 Materials and methods

2.1 Experimental site

The research was conducted in the Getasan area, the altitude of the research location is 600 m asl to 1 000 m asl. The entire Tuntang, Central Java, Indonesia watershed is located at a position of 110° 18' 26" to 110° 51' 01" east longitude and between 6° 45' 31" to 7° 26' 55" latitude, with an area of 156.7895 × 10^3 ha. In the upstream area, there are various types of agroforestry systems. The research was conducted from May to December 2017. Getasan District has a cool climate with sufficient rainfall to fertilize the soil. Getasan sub-district belongs to the B2 climate type with the characteristics of having 7 to 9 consecutive wet months and 3 to 4 dry months.

2.2 System agroforestry

The data collected are physical agroforestry data, including first is crop diversity in agroforestry, by making sample plots for each system of 100 m × 50 m, to calculate tree samples with plots of 20 m × 20 m. Then soil samples were taken at a depth of 0 cm to 20 cm, to calculate bulk density, soil moisture content (gravimetric method), and soil N (Kjeldahl method).

2.3 Forage treatment

The research begins with an initial survey of all the upstream locations of the Tuntang watershed and records the community's agroforestry system. From the survey, it is known that the cultivation of grass used for animal feed is carried out in agroforestry systems, namely agroforestry 1 (AGRO-1) and agroforestry 2 (AGRO-2). Observation of elephant grass begins with the pruning of elephant grass plants as high as 10 cm from the ground surface in July (including the dry season). The grass is allowed to grow back for 45 d, without fertilization. During this time, plant height was observed. On 45th d the grass was harvested to determine the fresh production, dry weight (DM), crude protein content (CP), and crude fiber content (CF). Defoliation treatment in the rainy season begins in October by trimming elephant grass plants as high as 10 cm from the ground. The grass is allowed to grow back for 45 d, without fertilization. Furthermore, it is applied the same as in the dry season, namely the height of the plant is observed. On 45th d the grass was harvested to determine the fresh production, dry weight (DM), crude protein content (CP), and crude fiber content (CF). In summary, the research design is 2 × 2 factorial with five replications. The first factor is the agroforestry system (AGRO-1 and AGRO-2). The second factor is defoliation (forage harvest) in the dry season (45 d) and the rainy season (45 d).

Observed variables were plant height, forage production, dry weight (DM= dry matter), crude protein (CP= crude protein), crude fiber (CF= crude fiber). In addition, soil samples were observed including soil texture, soil bulk density, pH, and total N.

Elephant grass forage samples were taken with a plot of 2.5 m × 2.5 m. From this area, one clump is taken. The forage sample was then weighed by wet weight. The dry matter was obtained by roasting 50 g of forage samples at 105 °C for 24 h. Crude protein content was measured by the Kjeldahl method and crude fiber by dissolving using strong acids [27–29]. Dry matter production is measured based on the dry matter content and fresh production, according to Equation (1)

$$\text{Production of dry matter (PBK)} = \text{Production of fresh weigh} \times \text{content of BK} \quad (1)$$

Crude protein content was calculated based on the nitrogen content as measured by the Kjeldahl method. with the following calculations (Equation 2) [30]

$$\text{Crude protein content} = N \times 6.25 \quad (2)$$

2.4 Statistic analysis

All data were collected and then tested for ANOVA (analyzed of variance) and to determine the difference between treatments was carried out by DMRT (Duncan's multiple range test) [31, 32].

3 Results and discussion

3.1 Ecobiophysics

The upland area of the Tuntang watershed has a mild climate with sufficient rainfall to fertilize the soil. Rainfall data for the last 8 yr of upland area of Tuntang watershed be seen that the upland area of Tuntang watershed includes a B2-type climate characterized by having 7 mo to 9 mo wet months (wet season) in a row and have a dry months amount 3 mo to 4 mo (Figure 1). According to Siregar [33], Zone B has 7 to 9 consecutive wet months. Crops can be cultivated during this period of 2 to 3 dry months. Careful planning is needed to grow crops throughout the year. A composite soil sample was collected previously to the experimental setting presenting the following values for the selected properties: total organic C= 1.2 g kg^{-1}, pH (1:5, soil: water) = 5.8, Ca = 0.8 cmol dm^{-3}, Mg = 0.6 cmol dm^{-3}, K = 0.15 cmol dm^{-3}. The area was Oxisol, the texture was loam.

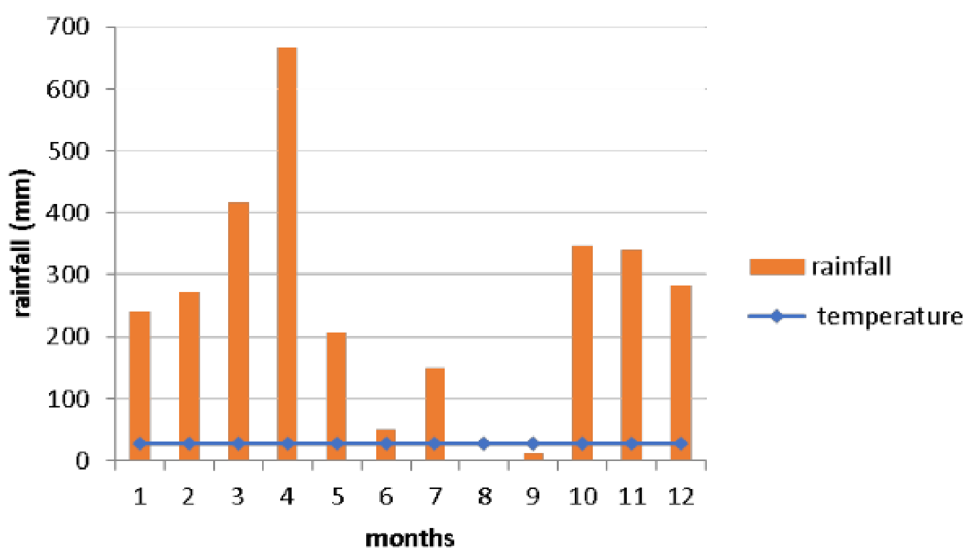

Fig. 1. Rainfall and temperature of research location

The results of the ANOVA analysis showed that the interaction between the agroforestry system and seasons was not significant, the agroforestry system was not significant in determining pH, while the seasons were real. Parameter weight volume of soil, agroforestry significant effect. ANOVA for soil N shows the real role of agroforestry and seasons. The interaction between agroforestry systems and seasons also significantly affected soil N (Table 1).

Table 1. Mean square of ANOVA.

	df	BD	pH	N	Plant height	Yield	DM	Crude Prot	Crude Fiber
Model	7	0.005 65*	0.152 42*	0.101 31*	519.57*	376.985*	48.167 1*	12.528 1*	36.498 8*
Block	4	0.001 83	0.113 75	0.008 48	11.80	18.075 0	2.142 6	0.300 4	3.003 4
Agroforestry	1	0.019 84*	0.002 00	0.456 02*	924.80*	1 155.200*	35.351 4*	11.355 2*	52.196 8*
season	1	0.007 60	0.578 00*	0.169 28*	2 645.0*	1 411.200*	270.627 2*	71.026 8*	188.682 2*
Agro*season	1	0.004 80	0.003 20	0.050 00*	20.00 0	0.200 0	22.620 6*	4.113 2*	2.599 2
Error	12	0.001 95	0.041 08	0.006 01	20.933	12.908 3	1.824 6	0.618 5	1.590 9
Total	19	0.063 05	1.560 0	0.781 42	3 888.20	2 793.80 0	359.065 9	95.120 0	274.583 6
CV		3.971	3.49	14.180 7	5.843 2	4.134 4	6.717 8	8.650 8	3.972 6
mean		1.11	5.80	0.547	78.30	86.900	20.10	9.09	31.75

Soil nitrogen in the AGRO-1 system showed higher than AGRO-2 both in the dry and rainy seasons. Total nitrogen was highest in the silvopastoral system in the dry season (0.84 %), while the agro-silvopastoral system was generally low. This is due to the silvopastoral system, where plants cover the soil throughout the year, both elephant grass and trees. In the agro-silvopastoral system, the terraces are planted with seasonal crops, the grass is on the bedside as reinforcement for the terrace and the trees are on the mound. The presence of nitrogen depletion every season causes low soil nitrogen. The highest acidity (pH) was in the wet season (6.0), while the bulk density was in the AGRO-1 agroforestry model (1.14 w v^{-1}) (Table 2).

Table 2. Soil characteristic of agroforestry.

Treatment		Bulk density (w v^{-1})	pH	Soil N (%)
AGRO-1	wet	1.11^{b}	6.0^{a}	0.84^{a}
AGRO-1	dry	1.18^{a}	5.5^{c}	0.55^{b}
AGRO-2	wet	1.07^{b}	5.9^{ab}	0.43^{c}
AGRO-2	dry	1.08^{b}	5.7^{bc}	0.35^{c}
System Agroforestry:				
AGRO-1		1.14^{a}	5.8^{a}	0.69^{a}
AGRO-2		1.08^{b}	5.8^{a}	0.39^{b}
Seasons:				
Wet		1.13^{a}	6.0^{a}	0.63^{a}
Dry		1.09^{a}	5.6^{b}	0.45^{b}

a,b,c Means with various letters in the same column are significantly different ($P < 0.05$); AGRO-1 wet= agroforestry system 1 in the rainy season, AGRO-1 dry = agroforestry system 1 in the dry season, AGRO-2 we t= agroforestry system 2 in the rainy season, AGRO-2 wet = agroforestry system 2 in the dry season.

3.2 Component of agroforestry

There are two agroforestry systems in the Getasan sub-district, namely Agroforestry 1 (AGRO-1) and Agroforestry 2 (AGRO-2). The condition of the sloping land forces the population to cultivate by utilizing the land as much as possible in order to prevent erosion. Most of the residents of the Getasan sub-district have livestock, namely dairy cows (*Bos taurus* Linnaeus, 1758) and or Etawah [*Capra aegagrus hircus* (Linnaeus, 1758)] goats so in order to meet their livestock feed needs, they have used the land for planting fodder crops, namely grass.

The AGRO-1 agroforestry system is carried out by farmers who have quite a lot of dairy cattle (Table 3). Generally, this system arises as a result of the awareness that vegetable yields usually drop at harvest, while the number of dairy cows that are owned every year increases, thus requiring more animal feed. The dominant tree plant for soil conservation and wood can also be taken is *Albizzia falcate* L.

Table 3. Agroforestry models.

No	Name	Benefit	Ecological function	Harvested
	AGRO-1 model			
1.	Component of tree: *Albizzia falcataria* L.	Wood building	soil conservation Soil fertility	10 yr
2.	underplant components: Napier grass (*P. purpureum*)	Grass	ground cover	Every month
3.	Livestock: cow	Milk	-	-
	AGRO-2 model			
1.	Component of tree: *Albizzia falcata* L.	Wood	soil conservation Soil fertility	10 yr
2.	Annual plant:			
	Corn (*Zea mays* L.)	Seeds	Cover crop	3 mo
	Cabbage	Leaf	Cover crop	3 mo
3.	Ground cover:			
	Napier grass.	Grass	Cover crop	Every month
4.	Livestock: cow	Milk	-	-

One of the agroforestry systems, namely AGRO-2 in the Getasan District, is a system that has combined livestock in the management system while the grass is planted at the bedside (Table 3). *A. falcate* plant is a terrace strengthening plant and is a tree plant whose wood is taken after 10 yr old. Farmers still plant vegetables and or maize in turns on their terraces dominantly, although in someplace rosewood and *Samanea saman* Merr. are found. Fruit plants in the form of trees are mostly avocado (*Persea americana* Mill.). The grass is an important requirement for cattle owned by farmers.

3.3 Forage yield and nutritive value

Both AGRO-1 and AGRO-2 agroforestry systems involve elephant grass. The grass is planted by farmers to meet the feed needs of dairy cows. In the AGRO-1 system, the grass is used as ground cover with tree stands. In the AGRO-2 system, the grass is planted on an inclined slope. The results of the ANOVA forage yield showed that the agroforestry system and seasons showed a significant effect, while the interaction between agroforestry systems and seasons had no effect. The results of dry matter ANOVA showed that the agroforestry system and seasons showed a significant effect, while the interaction between agroforestry systems and seasons also had a significant effect. The results of the crude protein ANOVA showed that the agroforestry system and seasons showed a significant effect, while the interaction between agroforestry systems and seasons also had a significant effect. The results of ANOVA crude fiber show that the agroforestry system and seasons show a significant effect, while the interaction between agroforestry systems and seasons has no effect.

Table 4. Plant height, forage yield, DM, CP, CF Pennisetum purpureum on different agroforestry models and seasons.

Treatment		Plant height (cm)	Forage yield (tons ha^{-1})	DM (%)	CP (%)	CF (%)
AGRO-1	wet	74.60	86.0	23.5^{a}	8.4^{b}	32.8
	dry	95.60	103.0	14.0^{c}	11.3^{a}	27.4
AGRO-2	wet	59.00	71.0	24.0^{a}	6.0^{c}	36.7
	dry	84.00	87.6	18.8^{b}	10.7^{a}	29.9
System Agroforestry:						
AGRO-1		85.10^{a}	94.5^{a}	18.77^{b}	9.8^{a}	30.1^{b}
AGRO-2		71.50^{b}	79.3^{b}	21.43^{a}	8.3^{b}	33.3^{a}
Seasons:						
	wet	66.80^{b}	78.5^{b}	23.78^{a}	7.2^{b}	34.8^{a}
	dry	89.8^{0a}	95.3^{a}	16.42^{b}	10.9^{a}	28.7^{b}

a,b,c Means with various letters in the same column are significantly different ($P < 0.05$); AGRO-1 wet = agroforestry system 1 in the rainy season, AGRO-1 dry = agroforestry system 1 in the dry season, AGRO-2 wet = agroforestry system 2 in the rainy season, AGRO-2 wet = agroforestry system 2 in the dry season. DM = dry matter, CP = crude protein, CF = crude fiber.

Plant height in the AGRO-1 system was higher (85.1 cm) than in the AGRO-2 system (71.5 cm). Season affected plant growth as indicated by lower plant height in the dry season (66.8 cm) than in the rainy season (89.8 cm) (Table 4.).

The AGRO-1 system has a better forage yield than the AGRO-2 system. This is due to the planting of AGRO-2 on a sloping plane as a reinforcement for the terrace, in addition to that, the number of plants per experimental plot is less. Forage dry matter varies between agroforestry systems and seasons. Agroforestry models and seasons on yield and nutritive value of elephant grass.

In the dry season, DM forage was high, which was achieved in both agroforestry systems. The lowest DM in the rainy season in the AGRO-1 system. It is suspected that the presence of shade in the AGRO-1 system causes the plant's vegetative period to belong; so DM is low. Crude protein in the AGRO-1 system was lower than that of AGRO-2. The highest protein content in the AGRO-1 system in the rainy season (11.30 %), the lowest in the AGRO-2 system in the dry season (6.0 %).

The crude fiber in the AGRO-2 system is higher than in the AGRO-1 system. The crude fiber content of forage grass in the dry season is higher than the crude fiber content in the rainy season.

4 Discussion

The planting area of the AGRO-1 system is generally undulating, with a slope of 8° to 150°, with tree and grass species. Elephant grass in the AGRO-1 system has better forage quality in terms of plant production and crude protein. There are fewer trees in AGRO-2 because the land is used for growing food crops. The grass is planted on the side of the terrace [34]. Bulk density was significantly lower in the undisturbed forest than in other land uses, suggesting that after approximately 10 yr of growth neither plantation lowered bulk density significantly from that of the active pasture [35].

The agroforestry system significantly affected plant height, forage yield, and crude fiber for elephant grass. Season also affects plant height, forage yield, and crude fiber of elephant grass forage. The interaction between agroforestry and seasons is not real. AGRO-1 has a higher plant height and forage yield than AGRO-2. This was due to the higher total N and pH at AGRO-1 (Table 2). The pH content of 6.9 and higher total N content means that the soil chemical fertility of the AGRO-1 system is better than that of AGRO-2. Hatfield [36] reported that changes in bulk density and soil nutrient profile are things that must be considered by rice producers. Changes in bulk density and nutrients in the soil profile were inconsistent between treatments and the way the sheep ate wheat crop residues. This shows the potential for enabling sheep to graze on wheat straw without damaging and affecting soil bulk density or soil profile. Meylan [8], consider the environmental importance of owning trees in agroforestry systems including habitats and shelters for biodiversity, carbon sequestration, microclimate control, and nitrogen fixation. In addition, many livelihoods in countries in the tropics are developing and rely on agroforestry as a subsystem, economic income, and other services, for example, selling timber and food.

Soil organic matter provides N sources of urease, and total N, so urease can indicate the level of soil fertility, especially the N content in the soil. Soil organic matter, total nitrogen, phosphorus, and alkaline hydrolyzable nitrogen rapidly decreased with increasing forest age [37–39]. Experimental agroforestry systems in Quesungual have great potential to improve soil fertility and biological health in certain areas with traditional slash and burn agriculture [40]. Experiments show the effect of land management on soil texture. Bulk density and soil water content increase while soil organic matter decreases with increasing soil depth. Soil microbiological diversity, microbial biomass, and respiration are influenced by plant intensity and diversity [41]. Changes in soil quality can affect the potential yield and number of harvests and the distribution of plant roots in the soil profile [19].

Plant height and forage yield on AGRO-1 are also higher than AGRO-2 in the rainy season compared to the dry season. More rainfall provides more water for nutrient dissolution, transpiration, and plant body composition. More rainfall (Figure 1) resulted in better plant height and forage yield in the rainy season. According to Wang [42], agroforestry systems have a larger area and longer time to retain water in deeper soil layers than monoculture systems, this indicates that agroforestry systems increase soil water retention capacity due to a deeper root system. Buyinza [43] reported that agroforestry systems can increase rainfall utilization compared to annual crops. Cardinael [44] described the combination of agroforestry hedges in using groundwater more efficiently from trees or plants, as water absorption from trees reaches deeper and starts earlier after irrigation than from sorghum, while plants can better utilize topsoil. Hong-Qun [45] reported that shrubs and grass under trees or on forest edges were able to develop well; so it was sufficient to feed Brown-eared birds in the form of grassroots, seeds, and fruits. It is therefore used to search for traces of Brown-eared birds at forest edges. Furthermore, Tingting [46] reported that among all environmental factors, topographic factors can cause different soils and then affect the composition of productivity and types of plant communities, quantitative characteristics of plant species and plant functional traits. It is generally assumed that crop productivity is lower on sun-exposed slopes than on shady slopes and higher on top of slopes than on lower slopes.

5 Conclusion

The conclusion of this study is that elephant grass in the AGRO-1 agroforestry system has better growth, production, and quality than AGRO-2. Growth, forage yield, protein content, and crude fiber content in the rainy season in the upland area of the Tuntang watershed were better than in the dry season. The best dry matter content was in AGRO-1 in the dry season and the highest crude protein content was in elephant grass grown in the AGRO-1 system in the rainy season.

The authors thank the Dean of Agriculture and Animal Science Faculty, Diponegoro University, Indonesia for allowing us to use the laboratory. Thanks are also expressed to the funders of the Indonesian state university operational agency (BOPTN).

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